Attachment 1
United States Antarctic Program
Communications Mission Needs Assessment

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Office of Polar Programs
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Contents

SUMMARY

Modern satellite communications have developed into mission-essential logistics infrastructure for the United States Antarctic Program (USAP). USAP mission communications between Antarctica and the U.S., within Antarctica and in the surrounding Antarctic waters are completely dependent upon satellite communications.

Service for Amundsen-Scott South Pole Station is especially challenging due to the lack of conventional geosynchronous service (either commercial or government/military). However, a solution to South Pole mission needs may also offer the opportunity to address other USAP needs and offer cost-effective solutions for NSF Antarctic communications mission needs.

Future broad band satellite communications service mission needs in support of USAP program operations in Antarctica can be roughly subdivided into 7 separate geographic regions, described in Table 1. Each geographic region is assigned a relative priority in terms of emphasis, with the South Pole Station region having the highest priority for this RFI.

Table 1 - Geographic Coverage Mission Needs

Geographic Coverage Mission Needs				
Coverage Region	**Description**	**Coverage**	**Requirement Type**	**Priority Rank**
1	South Pole Station	Spot	Threshold	1
2	West Antarctica	Zone	Objective	2
1	McMurdo Station	Spot	Objective	2
4	East Antarctica & Interior	Zone	Objective	2
2	Palmer Station	Spot	Objective	3
3	West Palmer Peninsula	Zone	Objective	3
n/a	Full Continent & Surrounding Ocean	Continental	Objective	4

These regions are depicted in Figure 1. Mission needs are distinguished as "Threshold" and "Objective," with meaning as follows:

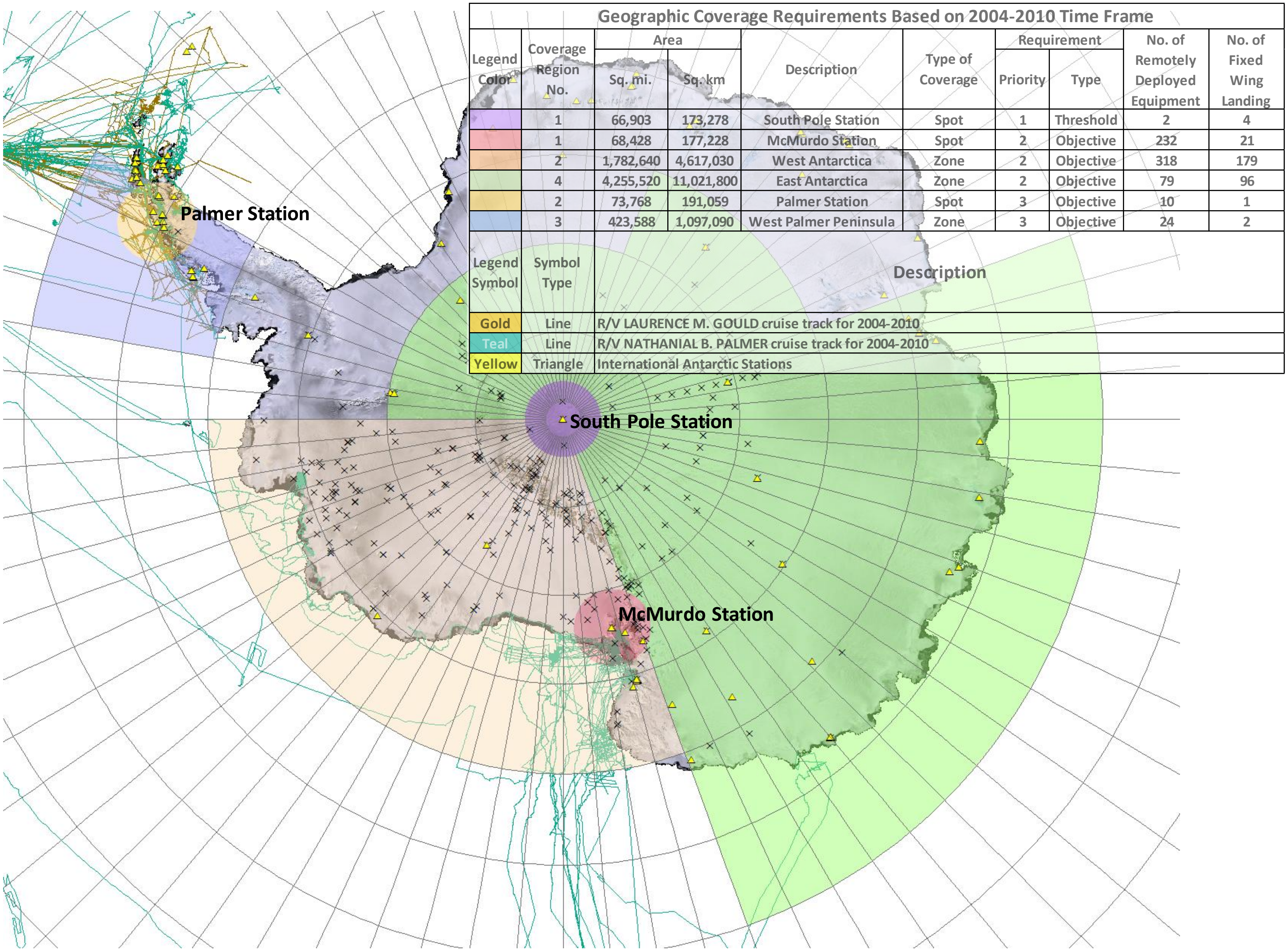
- Threshold mission needs: Mission essential needs. Solutions failing to meet threshold levels are considered a failure.
- Objective mission needs: Desired goal. Solutions meeting or partially meeting one or more objective levels are considered more desirable in terms of meeting needs.

The threshold and objective distinction applies both geographically and within a geographic region, as follows:

- Geography determines the relative priority or emphasis in the application of satellite-based resources and is intended to guide any trade-offs necessary between cost, capability and/or feasibility.
- Within any given geographic region there will be minimum (threshold) and desired (objective) performance mission needs. The distinction is made in order to guide trade-offs within that region, affecting cost, capability and/or feasibility.

South Pole Station represents the primary geographic requirement. However, the scope of USAP activity in Antarctica spans nearly the entire continent and includes the surrounding ocean regions, as depicted in Figure 1. Overviews of the additional regions are provided following the detailed discussion that follows for South Pole Station.

The table provided in Figure 1 below provides historical activity for the USAP over the 2004-2010 time period.



Geographic Coverage Requirements Based on 2004-2010 Time Frame									
Legend Color	Coverage Region No.	Area		Description	Type of Coverage	Requirement		No. of Remotely Deployed Equipment	No. of Fixed Wing Landing
		Sq. mi.	Sq. km			Priority	Type		
Purple	1	66,903	173,278	South Pole Station	Spot	1	Threshold	2	4
Red	1	68,428	177,228	McMurdo Station	Spot	2	Objective	232	21
Orange	2	1,782,640	4,617,030	West Antarctica	Zone	2	Objective	318	179
Green	4	4,255,520	11,021,800	East Antarctica	Zone	2	Objective	79	96
Gold	2	73,768	191,059	Palmer Station	Spot	3	Objective	10	1
Blue	3	423,588	1,097,090	West Palmer Peninsula	Zone	3	Objective	24	2

Legend Symbol	Symbol Type	Description
Gold	Line	R/V LAURENCE M. GOULD cruise track for 2004-2010
Teal	Line	R/V NATHANIAL B. PALMER cruise track for 2004-2010
Yellow	Triangle	International Antarctic Stations

Figure 1 - Geographic Coverage Mission Needs Based on 2004-2010 Time Frame

SOUTH POLE STATION MISSION NEEDS DISCUSSION

South Pole Station Service Mission Needs

Table 2 provides a summary estimate of forward-looking mission needs for Amundsen-Scott South Pole Station for the time frame 2015 - 2030[1].

Table 2 - Service Mission Needs for South Pole Station

Application	Service Type	Capacity	Connectivity	Quantity	Requirement Type
Science data transfer	Bulk data transfer, uni-directional outbound to CONUS	270-315 GB/day	Daily	1	Threshold
Main station IP network trunk	Bi-directional IP wide area network	20 Mb/s	8-10 hours/day, separated into 2 equal windows spaced 12 hours apart	1	Threshold
“	“	20-35 Mb/s	16-20 hours/day, separated into 2 equal windows spaced 12 hours apart	1	Objective
“	“	20-35 Mb/s	24 hours/day (continuous)	1	Objective

South Pole Station represents the primary geographic service requirement.

[1] For more information on South Pole Station, see: http://www.usap.gov/videoclipsandmaps/spWebCam.cfm

South Pole Station Mission Needs Summary

Daily bulk science data transfer (one-way, outbound from South Pole Station) represents the single largest mission need in terms of demand for bandwidth. Current short term demand estimates are:

Table 3 – Near Term Daily Bulk Science Data Transfer Mission Need

2011	2012	2013+
147.10 GB/Day	**≈ 180 GB/Day**	**≥ 180 GB/Day**

The primary drivers for bandwidth are the two major long term science research projects located at South Pole Station:

1. The international research consortium for the IceCube Neutrino Detector/Telescope lead by the University of Wisconsin/Madison, http://icecube.wisc.edu/ and

2. The South Pole (sub mm radio) Telescope lead by the University of Chicago http://pole.uchicago.edu/

Notional Future Requirements for Bulk Data Transfer

Transmission capacity for one-way bulk data outbound from the Pole of 180 Gbytes per day, minimum, beginning in 2012 is clearly indicated by the current demand forecasts. To this would be added an anticipated 25% reserve capacity (45 Gbytes/day) for retransmission capacity, with anticipated 25%-50% reserve capacity for future growth (45- 90 Gbytes/day). This amounts to some 270- 315 Gbytes/day before allowing for a supplement to account for transmission inefficiencies, which has been measured as 82%. This would result in a required link rate of 30 to 35 Mbps, based on the assumption that a full day is utilized to transmit the data requirement. A more conservative estimate would specify a 12 hour transfer period instead of 24 hours, resulting in a doubling of this estimate to 60 – 70 Mbps.

Notional Future Mission Need for Two-way IP Network Service

Link capacity should be suitable for a reasonable quality of service (QoS), sized for the peak demand during the maximum South Pole Station populations of the austral summer (150 – 250 people), given suitable modern WAN bandwidth management technology (proxy filters, packet shaping, TCP protocol enhancing proxies like SCPS, file caching, and advanced compression). This requirement has been observed from routine station IP network traffic utilization that has resulted in high levels of network utilization (≥ 80%) on existing WAN links during the austral summer. General IP network service supports operations, remote science management, and morale needs. An estimated threshold capability would be a 5 Mbps to 10 Mbps duplex TCP/IP network link. An objective would be a doubling of this to 10-20 Mbps. Ideally this would be full-period (i.e., 24x7x365). If this is unachievable, threshold requirement would be a constrained broadband access window either continuous, or broken into no more than 2 segments separated in time by 12 hours. NSF would supplement this with a thin-route connection via available commercial global LEO communications services.

This bi-directional requirement is separate and distinct from supporting the 270+ Gbytes/day one-way bulk file transfer, although both services can be combined onto the same carrier. Noting the combined mission need for bulk and two-way service, a threshold aggregate link in the range of 35-45 Mbps would be needed (doubled service to meet objective mission need would be 70-90 Mbps).

BACKHAUL CONSIDERATIONS

The ideal configuration terminates the communications link in CONUS, but if this is not possible then a landing location in a suitable mid-latitude location, such as at a new transit earth station facility in Australia or New Zealand where the data could be retransmitted by fiber to CONUS. If the Australia/ New Zealand option is not possible, it could be down-linked to McMurdo Station (Latitude: 77.88°S; Longitude: 166.73°E) for retransmission to CONUS. However, any transit through McMurdo would require a new solution for conventional GSO satellite service at McMurdo, plus the added delay if a second earth-satellite-earth hop is incurred. McMurdo presently has a full 54 MHz Ku transponder leased on Optus D1 (provided via an inter-governmental agreement with the NOAA Joint Polar Satellite System, JPSS, project), wherein NSF will receive a 10 Mbps outbound/19 Mb/s inbound share of a 60 Mb/s outbound/20 Mbps inbound service that is shared among NSF, NOAA/JPSS, EUMETSAT and NASA. The largest earth station supporting McMurdo is an 11 meter Ku antenna located at the Black Island Telecommunications Facility on an island approximately 22 miles south of McMurdo. Inbound capacity to McMurdo is limited by a combination of transponder beam pattern, power sharing, and McMurdo antenna aperture size.

South Pole Station Mission Needs Detailed Discussion

Background

The present South Pole Station broadband communications architecture consists of a patchwork of extended life geosynchronous satellites with limited direct communications contact between CONUS and the station. At 90° S latitude, South Pole Station is out-of-range of conventional station-kept geosynchronous satellites. Such contact is possible only when the satellite is inclined at least nine degrees. Service is presently provided as a by-product of a careful review that exploits the availability of a small number of satellites that have drifted into highly inclined orbits as a consequence of their age and continued operational status.

The importance of modern telecommunications for the science, operations, and health/welfare of South Pole Station and staff is summarized by the Blue Ribbon Panel[2] convened by NSF Director Neal Lane in 1996/97 to conduct a fundamental assessment of the infrastructure, management, logistics, and science pertaining to South Pole Station. In its discussion on telecommunications, the Panel commented:

> *Modern telecommunications with Antarctica enable technologically advanced research by connecting researchers and their data with colleagues in real time; enhance operational support with real time flow of management information; and improve morale by providing contact with family and other associates.*

NSF believes that the reliance upon chance availability of "extended life" satellites does not provide the certainty needed to sustain the science program.

Science Mission Needs Overview

Communications in support of science research programs conducted at South Pole Station have been discussed within the South Pole research community since 1987, when the first workshop was held for this purpose.

Current science research programs at South Pole Station include cutting-edge astronomy and astrophysics projects that involve the development of instrumentation utilizing sophisticated electronics and computing technology. These programs create large facility-class instruments that generate massive volumes of data on a daily basis. The sophisticated and collaborative nature of the research requires a significant interaction between deployed research teams and a multitude of science and engineering discipline experts located off-station within national and international teams. Experience has demonstrated that modern Internet based broadband communications support diverse functions such as: remote observation, instrument time-sharing among multiple investigators, remote troubleshooting, periodic software refresh and continuous development, timely data transfer for downstream analysis, timely feedback to experimental configuration and data acquisition protocols to adapt to changing experimental conditions and lines of inquiry, etc.

Broadband satellite data communications are used extensively by the astronomy and astrophysics programs in operation at South Pole Station. The two largest projects, IceCube Neutrino Telescope and South Pole (10-m radio) Telescope, consume the majority of daily bulk data transmission capacity now available and project a continued demand level into the future and are representative of the scope and importance of the evolving science program. IceCube has transitioned from its Major Research Equipment, Facilities, and Construction (MREFC)[3] construction status to production operations, having undergone extensive scientific merit review.[4] South Pole Telescope was specifically referenced in the 2000 National Academy

[2] Augustine, N. ed., The United States in Antarctica, Report of the U.S. Antarctic Program External Panel, Washington, D.C., April, 1997

[3] See: http://www.nsf.gov/pubs/2010/nsf104/nsf104.pdf , Large Facilities Manual, National Science Foundation, Publication No. NSF 10-4, September 2009, pg. 2

[4] See: http://icecube.wisc.edu/ for a general description of the IceCube Neutrino Observatory.

decadal review on astronomy and astrophysics as a recommended program and now performs outstanding scientific program observations [5]. The critical dependency of Antarctic astronomy on NASA satellite communications is noted in the recent 2010 National Academy decadal review.[6]

Operational Mission Needs

Mission Operations Business Case

The modernization of South Pole Station infrastructure has introduced added technological complexity that did not previously exist. The level of complexity of routine station management, operations and maintenance has increased as a result and creates challenges for managing a facility in such a remote location. Compounding these challenges is the added difficulty of the rotational contract staffing used for station operational staff. Personnel are not permanently assigned, but spend no more than one year on station and are hired on an annual contract basis, Consequently, South Pole Station experiences a significant annual churn in support personnel. A further challenge is the limited transition period and training received by incoming relief staff. Modern telecommunications and remote management provided by broadband satellite communications and IP networks enable permanent O&M and sustaining engineering staff located in the U.S. to compensate for these challenges. Technical experts from the various manufacturers/suppliers of critical systems are able to support South Pole staff via remote diagnostics. This is of specific importance to the critical power generation and facilities environmental control systems.

Morale and Welfare Business Case

Broadband communications also play an increasingly important role in the health and safety of all station personnel through the implementation of modern telemedicine capabilities. High-resolution digital video transmissions enable remote radiologists to guide real-time ultrasound diagnostic procedures administered by local staff. High-resolution digital video transmissions streamed via Internet-2 have supported real-time specialist supervision of locally administered clinical procedures when necessary.[7] [8] [9] [10] [11] [12] [13] [14] A 24-hour/day, 7-day-per-week broadband

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[5] See: http://pole.uchicago.edu/ for a general description of the telescope and the project. The SPT, as it is known, has the distinction of being one of 7 moderate-sized ground-based astronomy initiatives singled out as a national priority in the National Academy of Sciences Decadal Report on Astronomy (National Academy of Science, 2001, pp. 10, 13, 33, 37, 43, 128)

[6] National Academy of Science. (2010). New Worlds, New Horizons in Astronomy and Astrophysics (pre-publication release). Retrieved September 6, 2010, from The National Academy Press, pp. 3-15; http://www.nap.edu/catalog/12951.html

[7] Ardanuy, Philip E., *et al*, "Telepresence Enabling Human and Robotic Space Exploration and Discovery: Antarctic Lessons Learned," AIAA-2005-6756, Space 2005, Long Beach, California, Aug. 30-1 Sep, 2005; pp. 9-12

[8] Nielsen, Jerri, M.D., Ice Bound, A Doctor's Incredible Battle for Survival at the South Pole, Hyperion, New York, 2001

[9] Tsiao, Sunny, "READ YOU LOUD AND CLEAR!", The Story of NASA's Spacef light Tracking and Data Network, NASA SP-2007-4232, NASA History Series, 2008; p. 272

[10] "Telemedicine Link With South Pole Allows Remote Knee Surgery," NSF PR 02-61, National Science Foundation, July 17, 2002; http://www.nsf.gov/od/lpa/news/02/pr0261.htm?org=OLPA , retrieved December 13, 2010

capability will increase current tele-medical capabilities, permit transmission of vital diagnostic information at any time, day or night, and leverage on-site medical staff with virtually unlimited access to specialized medical expertise in the United States. Continuous access eliminates the present risk that medical emergencies must wait for limited daily satellite contacts. Enhanced off-site support in medical emergencies facilitates positive patient outcomes in such a remote, hostile environment.

South Pole Station remains a busy station, with summer populations climbing as high as 250 and winter populations averaging 50. IP network services enabled by broadband satellite service permit station staff to remain connected with family, transact personal business, and continue personal activities that they enjoy at home. Satellite communications, coupled with the Internet, have dramatically diminished the psychological impacts of the remoteness, harsh environment, extended isolation, and monotony of living and working for a year at South Pole Station. As the challenges for managing a complex technical presence at South Pole Station increase for both the science program and for station operations, the well-being needs of station staff increase as well. Access to music, news, video, telephone calls and video chats with family/friends, personal e-mail, social networking contacts, etc. all compensate for the difficulties of living and working at the station.

Description of Present Systems

South Pole TDRSS Relay

The South Pole TDRSS Relay (SPTR) is supported by a newly constructed 4.5 meter Ku/S Band antenna (Ka precision) providing full motion el/az tracking. The SPTR earth station provides a dual simultaneous link at Ku-band single access return (KSAR) and S-band single access return/forward (SSAR/F). The KSAR link supports a 150 Mb/s carrier that is fully waveform compliant with NASA standard Space Ground Link Terminal (SGLT) specifications for the White Sands Complex (WSC).

Data throughput efficiency has been benchmarked at 82% based on active testing (which implies that the actual payload data throughput is 150 x 0.82 = 123 Mb/s), with this efficiency factor including IP protocol overhead and retransmission effects of the commercial file transfer application (FileCatalyst™ by Unlimi-Tech Software Inc. of Ottawa, CA). This results in a figure of merit of 53 GB/hr of file transfer capacity, or 212 GB/day when limited by the 4 hr/day

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[11] "Satellite Used in Polar Research Enters Retirement," Press Release 10-109, National Science Foundation, June 25, 2010; http://www.nsf.gov/news/news_summ.jsp?cntn_id=117228&org=NSF&from=news, retrieved December 13, 2010

[12] "NSF Weighs Options for Treating South Pole Patient," NSF PR 01-28, National Science Foundation, April 11, 2001; http://www.nsf.gov/od/lpa/news/press/01/pr0128.htm, retrieved December 13, 2010

[13] Otto, Christian, M.D., "South Pole Station: An Analogue for Lunar/Mars Outpost Medical Operations?," Universities Space Research Association, Division of Space Life Sciences; http://www.dsls.usra.edu/20060425.pdf, retrieved December 13, 2010

[14] Otto, Christian, M.D., "Antarctica as a Long Duration Mission Analog," 2010 NASA Human Research Program Investigator's Workshop, Westin Galleria, Houston, Texas, February 3-5, 2010; http://www.dsls.usra.edu/meetings/hrp2010/pdf/Thursday/Otto.pdf, retrieved December 14, 2010

scheduling access. A simultaneous bi-directional Internet link operating at a nominal 5 Mb/s is provided by the SSAR/F service.

NASA TDRSS Space Network service is provided on a scheduled basis, with weekly schedules produced. Due to satellite constellation deployment/management constraints, NSF presently has access to only F4, F5, and F6.

GOES-3

An asymmetric (1.5 Mb/s outbound, 1 Mb/s inbound) S/L-Band IP link is implemented via the VISSR data product retransmission transponder on the aged GOES-3 weather satellite. This satellite has been transferred to NSF control from NOAA. The University of Miami Rosenstiel School of Marine and Atmospheric Sciences (UM/RSMAS) provides satellite TT&C and teleport services using a 20 meter prime antenna with VHF back-up for TT&C. South Pole Station utilizes a 9 m Vertex commercial C-Band limited motion antenna converted for this purpose. The link is gain limited in the satellite-South Pole direction, resulting in the asymmetric link rates. South Pole shares transponder power and bandwidth with typically one seasonal deep field camp which uses a 2 meter fixed antenna to provide a 32 kb/s thin IP link for the camp.

At the present time, due to the fragmentation of the SPTR SSAR/F IP network service, South Pole Station traffic is tending to favor the GOES link (GOES provides a contiguous 7 hour block of service), which is causing bandwidth congestion on the link and requiring more sophisticated bandwidth management techniques using packet shaping.

Iridium Inverse Multiplex Communications Systems (Iridium IMCS)

In order to address the need for near-real-time communications in support of the major science programs and in order to facilitate more efficient station operations (especially during the austral summer when there is a high op tempo and tight mission ops coupling with the logistical support provided by airlift from McMurdo Station), a customized inverse multiplex thin TCP/IP WAN network link was implemented to provide essential email and streaming real-time science data communications during the broadband satellite window gap. Twelve Iridium standard modems (each at a raw link rate of 2.4 kbps) were ganged into an effective aggregate link of 22 kbps (once overhead is discounted) using the standard Cisco™ router IOS. Sufficient demand is occurring, primarily from the IceCube project, for expanded service to allow for additional real-time communications that this link may be expanded in the near future to its maximum feasible capacity (~ 56 kbps).

The IMCS system remains in use due to greater robustness for dropped calls resulting from Iridium constellation management required at extreme high latitudes.

DEEP FIELD ACTIVITIES MISSION NEEDS SUMMARY

Seasonal field camps and related aviation support remote science instrumentation sites, and terrestrial tractor traverses operate during the austral summer (Nov-Jan).However, there are some scientific instrumentation sites such as the Automatic Geophysical Observatories (AGO), crustal rebound/GPS measurements sites (POLENET)[15], etc. that operate year-round and currently use some form of Iridium single channel or Short Burst Data transmission service. At the present time, these sites are supported by a mix of single channel Iridium voice and/or data units, small scale Iridium IMCS systems (4 channel, or a net 7.2 kbps realized capacity), HF radio (voice only), and GOES thin-link transportable (only 2 or 3 terminals available, providing 32 kbps per terminal). The following summarizes the current forecast of deep field activity.

The 2010/2011 austral season utilization of NSF provisioned Iridium SIMs[16] (obtained via DOD support) may be used as a benchmark for estimating mission needs until additional research community outreach occurs. The USAP currently uses 213 SIMs for operational support purposes and 167 for direct science mission support purposes, continent-wide, when averaged for the entire year.

Growth has been experienced in recent years for the deployment of large deep field camps in the West Antarctic region with populations ranging from small (~20 people), mid-range (~50 people)[17], and large (~90-100 people). There most deep field activity occurs with the airlift provided by the ski-equipped LC-130 fleet[18] or by small contract fix-winged aircraft (De Havilland Twin Otter, Bassler DC-3)[19]. However, the South Pole Overland Traverse has now proven a traverse route between South Pole Station and McMurdo Station through West Antarctica and has begun production operations.[20] This has lead to the development of a dedicated science traverse capability that is expected to operate in West Antarctica, with possible extended operations in East Antarctica, possibly in the vicinity of the Antarctic Gamburtsev Province region of sub-surface mountains.[21] The following figures provide an idea the numbers of deployed personnel during the recent austral summer field seasons and the extent and type of deep field activity occurring both seasonally in austral summers and year-round (year-round applications represent autonomous instrumentation).

The intensity of the USAP deep field program is characterized by the following two plots. Figure 2 shows the numbers of personnel deployed in the field (vertical axis) v. date for two successive Austral Summer seasons (2009/2010 and 2010/2011). Figure 3 shows the

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[15] See: http://www.usap.gov/scienceSupport/sciencePlanningSummaries/2008_2009/scienceSummariesAction.cfm?formAction=detail&ID=270

[16] Subscriber Identity Module

[17] See: http://antarcticsun.usap.gov/science/contentHandler.cfm?id=1573

[18] See: http://www.109aw.ang.af.mil/

[19] See: http://www.borekair.com/index.php/services/remote-services/antarctic

[20] See: http://antarcticsun.usap.gov/features/contentHandler.cfm?id=1362

[21] See: http://antarcticsun.usap.gov/science/contenthandler.cfm?id=1278

corresponding number of discrete encampments (vertical axis) v. date for the same two successive Austral Summer seasons.

Additional information on USAP deep field science research programs may be obtained from: http://www.usap.gov/usapgov/researchersAndScienceProjects/index.cfm?m=5

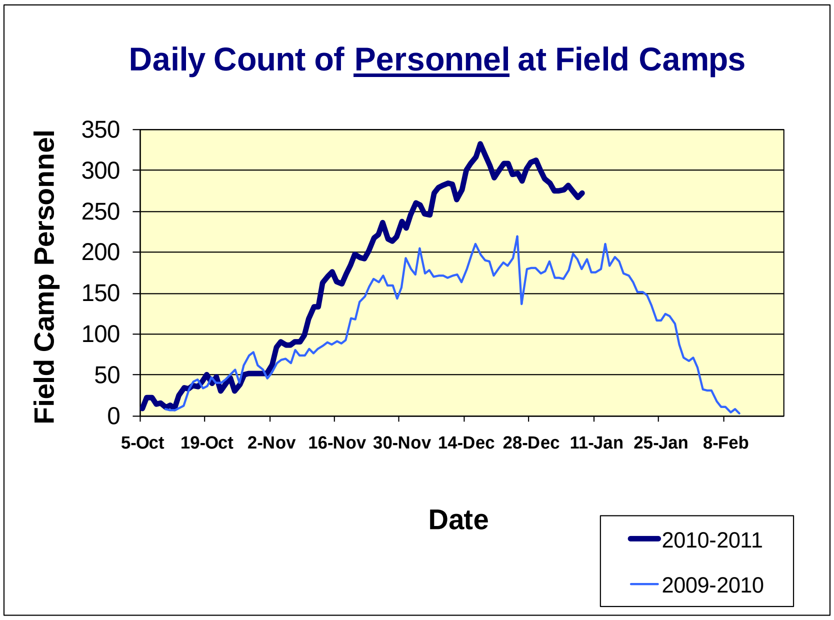

Figure 2 - USAP Deep Field Population Trends

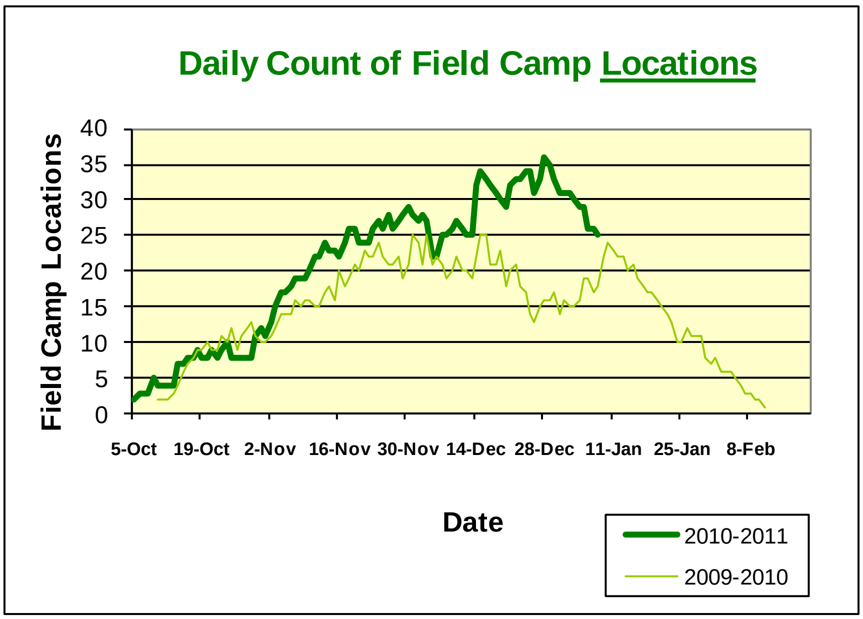

Figure 3 - USAP Deep Field Camp Volume Trends

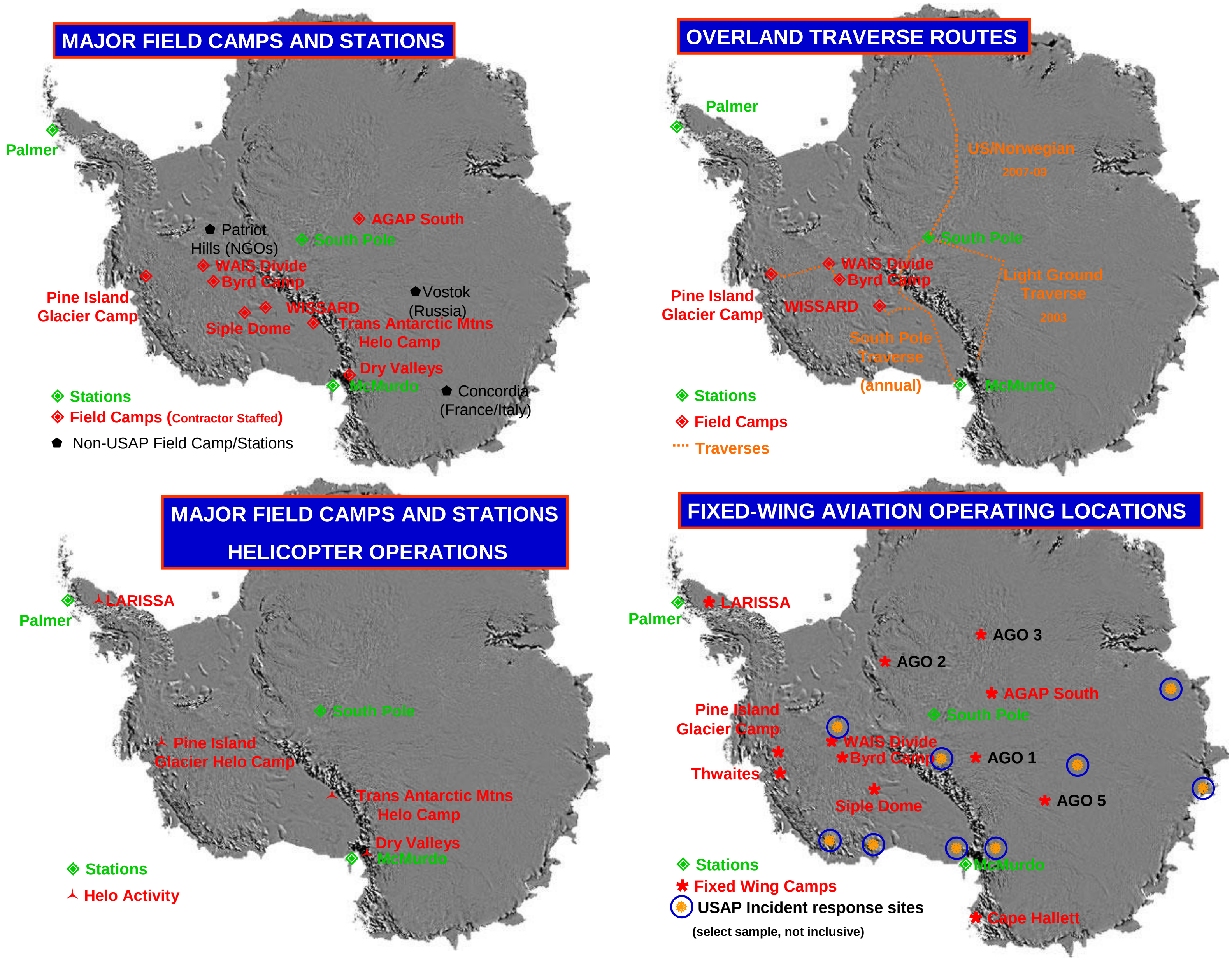

Figure 4 - Typical USAP Deep Field Operating Locations

Geospatial Regional Capability Requirement							
Coverage Region	Description	Application	Service Type	Capacity	Connectivity	Quanity	Requirement Type
2	**West Antarctica**	Major deep field camp IP network trunk	Bi-directional IP wide area network	1 Mb/s	16-20 hours/day, separated into 2 equal windows spaced 12 hours apart	3	Threshold
			Bi-directional IP wide area network	1 Mb/s	24 hours/day (continuous)	3	Objective
		Comm-on-the-move terrestrial	Bi-directional IP wide area network	9.6 kb/s	24 hours/day (continuous)	4	Threshold
			Voice, PSTN	2.4 kb/s	24 hours/day (continuous)	75	Threshold
			Bi-directional IP wide area network	128 kb/s	24 hours/day (continuous)	4	Objective
		Comm-on-the-move aeromobile	Burst Data, automatic dependent surveillance; 2-way messaging	~150 bits	24 hours/day (continuous)	20	Threshold
			Voice, PSTN	2.4 kb/s	24 hours/day (continuous)	20	Threshold
			Voice, UHF Tacsat (MUOS compatible)	9.6 kb/s	24 hours/day (continuous)	10	Objective
		Autonomous Instrumentation	Bi-directional Burst Data	~150 bits	24 hours/day (continuous)	50	Threshold
		Autonomous Instrumentation	Bi-directional IP wide area network	9.6 kb/s	24 hours/day (continuous)	20	Objective
			Bi-directional IP wide area network	128 kb/s	24 hours/day (continuous)	20	Objective

Figure 5 - Threshold and Objective Mission Needs Within the West Antarctica Coverage Region

Geospatial Regional Capability Requirement							
Coverage Region	Description	Application	Service Type	Capacity	Connectivity	Quanity	Requirement Type
4	**East Antarctica & Interior**	Comm-on-the-move terrestrial	Bi-directional IP wide area network	9.6 kb/s	24 hours/day (continuous)	1	Threshold
			Voice, PSTN	2.4 kb/s	24 hours/day (continuous)	10	Threshold
			Bi-directional IP wide area network	128 kb/s	24 hours/day (continuous)	1	Objective
		Comm-on-the-move aeromobile	Burst Data, automatic dependent surveillance; 2-way messaging	~150 bits	24 hours/day (continuous)	20	Threshold
			Voice, PSTN	2.4 kb/s	24 hours/day (continuous)	20	Threshold
			Voice, UHF Tacsat (MUOS compatible)	9.6 kb/s	24 hours/day (continuous)	10	Objective
		Autonomous Instrumentation	Bi-directional Burst Data	~150 bits	24 hours/day (continuous)	20	Threshold
		Autonomous Instrumentation	Bi-directional IP wide area network	9.6 kb/s	24 hours/day (continuous)	5	Objective
			Bi-directional IP wide area network	128 kb/s	24 hours/day (continuous)	5	Objective

Figure 6 - Threshold and Objective Mission Needs Within the East Antarctica and Interior Coverage Region

McMURDO STATION MISSION NEEDS DISCUSSION

McMurdo Station is the largest of the three year-round U.S. Antarctic stations and is located on the southern tip of Hut Point Peninsula, Ross Island, Antarctica. McMurdo serves as the main logistical gateway for the majority of U.S. program activity within Antarctica, providing port and aerodrome facilities supporting research programs conducted at McMurdo Station, the deep interior of Antarctica and South Pole Station. Station populations can reach ~ 1200 personnel during the peak of the austral summer season (Oct. – Feb.), while reducing to ~ 150-200 during the austral winter season (Mar. – Sep.)[22].

Figure 7 - McMurdo Station, as Seen Looking North from Winter Quarters Bay

McMurdo Station hosts two major U.S. Federal agency tenants who conduct data communications intensive operations: NASA Ground Networks (NASA/GN) and the NOAA Joint Polar Satellite System (JPSS). As part of a multi-agency collaboration, NSF is hosting the construction of 2 JPSS receptor earth stations that will collect data from the new civil operational environmental satellite system that will replace the NOAA Polar Orbiting Environmental Satellites. As a continuation of a collaboration begun in the early 1990's to support data acquisition during the RADARSAT-1 synthetic aperture radar Antarctic Mapping Mission, NSF also hosts the NASA/GN McMurdo Ground Station (MG1) and its planned expansion (MG2)[23]. Jointly, these space data earth stations will collect data from the present U.S. Air Force Defense Meteorological Satellite Program (DMSP), the forthcoming JPSS-1&2 civil operational

[22] For more information on McMurdo Station, see: http://www.usap.gov/videoclipsandmaps/mcmwebcam.cfm
[23] See: http://antarcticsun.usap.gov/features/contenthandler.cfm?id=2392

environmental satellites, the EUMETSAT MetOp satellite system[24], and various NASA polar low earth orbit and launch support activities.

NOAA, NASA and NSF have teamed resources to produce the Multi-Mission Communications System (MMCS)[25] that supports these activities via NSF provided satellite communications earth station infrastructure at its Black Island Telecommunications Facility, located approximately 20 miles south of McMurdo to permit an unobstructed view of the Pacific geosynchronous satellite arc[26] westward from 183°W longitude. Due to McMurdo's high latitude of 78°S, satellites appear no higher than 3.5° above the horizon.

The Black Island Facility supports two satellite earth stations, an 11m Ku-Band (active) and a 7.3 m Ku-Band (inactive). Via leased Ku-Band transponder services on the SingTel Optus D1 satellite, a 60 Mb/s outbound/20 Mb/s inbound service will be provided by the 11 m earth station in January, 2012. At the present time, NSF receives 10 Mb/s outbound and inbound service. When fully commissioned in 2012, NSF will receive 10 Mb/s outbound/19 Mb/s inbound from this shared resource.

Future mission needs from NOAA, NASA and their respective supported clients (EUMETSAT, Air Force Weather Agency/DMSP, future NASA polar LEO science missions), as well as possible commercial LEO electro-optic satellite operator interests, potentially exist that would far outstrip the capacity of the outbound bandwidth available to the MMCS. McMurdo Station has the potential to evolve into a Southern Hemisphere equivalent of the major polar LEO space data acquisition and command service that has developed at Svalbard in the Northern Hemisphere. Access to greater broadband communications for real-time forwarding of data and commands currently constrains the greater utilization of McMurdo Station's high southern latitude for polar LEO satellite operations support.

In addition to the major Federal tenants supported, McMurdo Station has the same operational communications mission needs as discussed in detail for South Pole Station, amplified by the greater population and the major operational logistics support functions provided by McMurdo.

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[24] Product and Services News, Improving the Timeliness of Metop-A Global Data UPDATED 07/04/2011, EUMETSAT, March 31, 2011; http://www.eumetsat.int/Home/Main/News/ProductServiceNews/805204?l=en , retrieved April 11, 2011

[25] Paciaroni, J.; Higgins, C.; Jamilkowski, M. L.; NPOESS McMurdo Multimission Communications System, American Geophysical Union, Fall Meeting 2010, abstract #IN43B-1405; December 2010; http://adsabs.harvard.edu//abs/2010AGUFMIN43B1405P , retrieved April 11, 2011

[26] See: http://antarcticsun.usap.gov/features/contenthandler.cfm?id=2114

Coverage Region	Description	Application	Service Type	Capacity	Connectivity	Quanity	Requirement Type
1	**McMurdo Station**	NOAA-NASA-EUMETSAT-DWSS Multi-mission Communications System	Assymetric bi-directional IP wide area network	60 Mb/s outbound 5 Mb/s inbound	24 hours/day (continuous)	1	Objective
		Main station IP network trunk	Bi-directional IP wide area network	25 Mb/s	24 hours/day (continuous)	1	Objective
			Bi-directional IP wide area network	50 Mb/s	24 hours/day (continuous)	1	Objective

Figure 8 - Threshold and Objective Mission Needs for McMurdo Station

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PALMER STATION MISSION NEEDS DISCUSSION

Palmer Station is the smallest of the three year-round U.S. Antarctic stations and is located on southwestern shore of Anvers Island in the Antarctic Peninsula. Palmer Station represents the sole permanent U.S. presence in Antarctica in the Western Hemisphere. Palmer Station supports primarily marine and biological science programs. Palmer Station is accessible by vessel on a year-round basis (currently serviced by the R/V *Lawrence M. Gould*) and supports a maximum population of ~50.

In addition to marine/biological science, Palmer Station supports a polar low earth satellite direct read-out ground receiving station for the recovery of weather satellite imagery (NOAA POES and DMSP) for operational weather forecasting, support to USAP vessel navigation in sea ice, seasonal support for USAP fixed wing aviation activities and for general science research. Operational uses of the recovered satellite imagery generate the need for data transmission outbound from Palmer Station.

Palmer Station possesses the same basic operational support mission needs as documented in detail for South Pole Station (e.g., telemedicine, telephone, data network, morale/welfare, etc.), albeit at a lesser demand level due to the smaller station population. When the research vessels are docked at Palmer Station, wireless LAN links are established to connect the vessel networks to the Station to enable the vessels to utilize the Station's satellite communications resources.

Located at 64°S, Palmer Station has a reasonable view of the Atlantic and Americas geosynchronous communications arc, with satellite elevations approaching 15°.

Figure 9 - Palmer Station

Palmer Station utilizes leased commercial satellite services providing a 3 Mb/s bi-directional service on a global C-Band beam via a single 4.0 m earth station.

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Coverage Region	Description	Application	Service Type	Capacity	Connectivity	Quanity	Requirement Type
2	**Palmer Station**	Main station IP network trunk	Bi-directional IP wide area network	3 Mb/s	24 hours/day (continuous)	1	Objective
			Bi-directional IP wide area network	20 Mb/s	24 hours/day (continuous)	1	Objective

Figure 10 - Threshold and Objective Mission Needs for Palmer Station

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MARITIME ACTIVITIES MISSION NEEDS SUMMARY

The present era in USAP oceanography started with the R/V *Nathaniel B. Palmer*. The *Palmer*, launched in 1992, is the first modern era U.S. commercially built and owned icebreaker. Classed at ABS-A2, it can nominally break 1-meter (3-feet) of ice at a steady 5.6 km/hr (3 knots). The ship was built from keel up as an ice breaking research vessel. The 94-meter (308-foot) vessel operates year around in all areas of the Southern Ocean, although operations in recent years have focused in the Ross Sea region. The *Palmer* has the capacity to berth a maximum of 37 scientists and support technicians and a crew of 22 with a 75 day maximum mission endurance.

The newest ship in the USAP fleet is the R/V *Laurence M. Gould*. The 70-meter (230-foot) *Gould* is classed as an ABS A1 Icebreaker. The Gould was purpose built for the dual role of research and Palmer Station supply. The *Gould* typically operates around the Antarctic Peninsula, making frequent research and/or resupply cruises each year. The *Gould* has the capacity to berth a maximum of 26 science and support technicians plus an additional 10 when using short term berthing vans secured to the deck. The *Gould* is also capable of supporting a maximum mission endurance of 75 days.

Figure 11 - USAP Science Research Vessel Fleet (2011)

At present, the *Palmer* and the *Gould* operate under charter from the builder Edison Chouest Offshore (ECO), Galliano, Louisiana. Each is currently outfitted with INMARSAT Fleet

Broadband communications terminals owned by NSF for science communications, augmenting the INMARSAT Fleet 77 terminals installed by ECO to meet safety of life at sea mission needs.

Both ships were designed to accommodate biological, oceanographic, geological, and geophysical experiments. Research equipment includes a seismic system, a portable radioisotope laboratory, and dedicated oceanographic instrumentation (e.g., conductivity-temperature-depth). Both ships have a deep-sea trawl winch and hydrographic winches, cranes, an interior staging area with telescoping side boom, and starboard and aft A-frames. Both also have satellite navigation, radar, precision depth recorders, computer networks, and electronic mail systems.

INMARSAT Fleet Broadband communications service is provided as part of a collaboration funded by NSF and managed by the Woods Hole Oceanographic Institution, providing support to the academic research fleet.[27]

The use of Fleet Broadband is limited by the current transmission rate of the service, which places constraints on advanced applications such as educational outreach requiring quality interactive video, and by coverage voids in the INMARSAT POR and AOR-West footprints in an area of important scientific significance (~ 74°S, 150°W) that prevent the transmission of advanced satellite remote sensing imagery needed to facilitate ship navigation in the changing Antarctic pack ice conditions.

Based on the general populations of ship personnel, both science mission-related and ship crew, the research vessels can be considered the equivalent of a small Antarctic research station. Using Palmer Station as an analog, one may conclude that an appropriate sizing for satellite communications would be on the order of 1 Mb/s to allow for a full complement of research, ship operations, and crew/staff morale communications on a continuous basis.

A significant research program is supported by the *Gould* in the West Palmer Peninsula region – the Long Term Ecological Research Network's Palmer Station field site, covering an area of roughly 14,000,000 HA (54,054 mi²).[28]

Additional information about the USAP marine science research program and research vessels may be obtained from:
http://www.usap.gov/usapgov/vesselScienceAndOperations/index.cfm?m=3

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[27] See: http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0956734
[28] See: http://www.lternet.edu/sites/pal/

Geospatial Regional Capability Requirement							
Coverage Region	Description	Application	Service Type	Capacity	Connectivity	Quanity	Requirement Type
2	**West Palmer Peninsula**	Comm-on-the-move maritime	Bi-directional IP wide area network	1 Mb/s	24 hours/day (continuous)	2	Objective
		Comm-on-the-move aeromobile	Burst Data, automatic dependent surveillance; 2-way messaging	~150 bits	24 hours/day (continuous)	5	Threshold
			Voice, PSTN	2.4 kb/s	24 hours/day (continuous)	5	Threshold
		Comm-on-the-move terrestrial	Voice, PSTN	2.4 kb/s	24 hours/day (continuous)	15	Threshold
		Autonomous Instrumentation	Bi-directional Burst Data	~150 bits	24 hours/day (continuous)	20	Threshold
		Autonomous Instrumentation	Bi-directional IP wide area network	9.6 kb/s	24 hours/day (continuous)	5	Objective
N/A	Full Continent & Surrounding Ocean	Comm-on-the-move maritime	Bi-directional IP wide area network	1 Mb/s	24 hours/day (continuous)	2	Objective
		Comm-on-the-move aeromobile	Burst Data, automatic dependent surveillance; 2-way messaging	~150 bits	24 hours/day (continuous)	5	Threshold
			Voice, PSTN	2.4 kb/s	24 hours/day (continuous)	5	Threshold

Figure 12 - Threshold and Objective Mission Needs within the West Palmer Peninsula and the General Surrounding Ocean Coverage Region